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Assessment of Türkiye's renewable energy, economic growth, and emissions (2000-2021): A decision-making approach with MAXC and MUTRISS models

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Abstract

This study investigates Türkiye's performance in renewable energy utilization, economic growth, and carbon emissions between 2000 and 2021 through the application of multi-criteria decision-making (MCDM) methods. By employing MAXC and MUTRISS as decision-making models, this study facilitates the integrated assessment of economic development and environmental sustainability objectives. The MAXC-based analysis identifies economic growth (GDP) as the most influential criterion aligned with national development objectives, while environmental sustainability emerges as a secondary yet essential component. Renewable energy consumption is underscored as a fundamental element of sustainable development. The MUTRISS findings indicate that Türkiye exhibited its highest overall performance in 2004, whereas 2007 and 2008 were marked by the lowest performance levels, potentially reflecting the adverse effects of economic downturns and environmental pressures. To validate the robustness of the applied methods, comparative analyses were conducted with other MCDM techniques. Spearman rank correlation results reveal strong concordance between MAXC and objective weighting methods such as Entropy, MPSI, and IDOCRIW, while showing a negative correlation with CILOS. Conversely, MUTRISS demonstrated moderate positive correlations with PIV, SAW, and CoCoSo, indicating relatively lower ranking consistency. The findings contribute to the methodological evaluation of MCDM tools and emphasize the importance of integrated economic–environmental policy approaches in sustainability assessments.

Keywords: Sustainable Development, Renewable Energy, MAXC & MUTRISS Methods, Economic and Environmental Performance

JEL Codes: Q01, Q42, C44, Q56

Türkiye'nin yenilenebilir enerji, ekonomik büyüme ve emisyonlarının değerlendirilmesi (2000-2021): MAXC ve MUTRISS modelleri ile bir karar verme yaklaşımı

Öz

Bu çalışma, Türkiye'nin 2000-2021 yılları arasındaki yenilenebilir enerji kullanımı, ekonomik büyüme ve karbon emisyonu performansını çok kriterli karar verme (ÇKKV) yöntemlerini uygulayarak incelemektedir. Ekonomik kalkınma ve çevresel sürdürülebilirlik hedeflerinin birlikte değerlendirilmesini sağlayan bu çalışmada, karar verme sürecinde MAXC ve MUTRISS modelleri kullanılmıştır. MAXC tabanlı analiz, ekonomik büyümeyi (GSYİH) ulusal kalkınma hedefleriyle uyumlu en etkili kriter olarak tanımlarken, çevresel sürdürülebilirlik ikincil ancak önemli bir bileşen olarak ortaya çıkmaktadır. Yenilenebilir enerji tüketimi, sürdürülebilir kalkınmanın temel bir unsuru olarak vurgulanmaktadır. MUTRISS bulguları, Türkiye'nin 2004 yılında en yüksek genel performansını sergilediğini, 2007 ve 2008 yıllarında ise ekonomik gerilemelerin ve çevresel baskıların olumsuz etkilerini yansıtabilecek şekilde en düşük performans düzeylerine ulaştığını göstermektedir. Uygulanan yöntemlerin sağlamlığını doğrulamak için diğer ÇKKV teknikleriyle karşılaştırmalı analizler yapılmıştır. Spearman sıra korelasyonu sonuçları, MAXC ile Entropi, MPSI ve IDOCRIW gibi objektif ağırlıklandırma yöntemleri arasında güçlü bir uyum olduğunu ortaya koyarken, CILOS ile negatif bir korelasyon göstermektedir. Buna karşılık, MUTRISS, PIV, SAW ve CoCoSo ile orta düzeyde pozitif korelasyonlar göstererek nispeten daha düşük sıralama tutarlılığına işaret etmiştir. Bulgular, ÇKKV araçlarının metodolojik değerlendirmesine katkıda bulunmakta ve sürdürülebilirlik değerlendirmelerinde entegre ekonomik-çevresel politika yaklaşımlarının önemini vurgulamaktadır.

Anahtar Kelimeler: Sürdürülebilir Kalkınma, Yenilenebilir Enerji, MAXC ve MUTRISS Yöntemleri, Ekonomik ve Çevresel Performans

JEL Kodları: Q01, Q42, C44, Q56

Introduction

Environmental change and its harmful ecological effects are among the most pressing environmental challenges facing the modern world. Energy consumption, particularly the reliance on carbon-based fuels, is one of the foremost human activities that

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significantly contributes to environmental change. Carbon dioxide (CO_2), released when carbon-based fuels are burned, has a significant impact on the greenhouse effect and is a major contributor to global warming. Transitioning to renewable energy sources (RES) not only helps protect the environment, but is also essential for reaching key objectives like economic growth and energy security (Dogan et al., 2020, p. 1;Inglesi-Lotz, 2016, p. 58).

In contrast to fossil fuels, which can harm the environment, renewable energy consists of sources that can be produced sustainably. Implementing energy solutions from wind, solar, hydro, biomass and geothermal sources plays a crucial role in addressing pollution and global warming by reducing carbon dioxide emissions. While developed countries promote sources of renewable energy to ensure energy security and control emissions of greenhouse gases, developing countries see them as an opportunity to solve rural electrification and electricity access problems. In this regard, the spread of RES is crucial for both environmental and economic sustainability (Inglesi-Lotz, 2016, p. 58; Ocal and Aslan, 2013, p. 494; Dogan et al., 2020, pp. 1-2; Ağbulut et al., 2023, p. 1).

The dialogue surrounding energy consumption and economic advancement has prominently featured the relationship between economic progress and environmental sustainability. Although the strong connection between economic growth and energy consumption is well recognized, promoting renewable energy sources is crucial to mitigate the environmental damage resulting from this growth. Unlike fossil fuels, renewables offer clean energy options that do not harm the environment and are essential for achieving sustainable growth. For the realization of environmental targets and the enhancement of economic development, the role of integrating renewable energy sources cannot be overstated (Inglesi-Lotz, 2016, p. 58; Dogan et al., 2020, pp. 1-2). To reduce fossil fuel dependency and ensure sustainable economic growth, increased investment in renewable energy is essential. Turkey is committed to raising renewable energy production in order to diminish its dependence on imported energy and to achieve its sustainable development objectives. However, economic and social challenges as well as environmental issues should be taken into account in this transition process. In other words, this transition process is a process that requires multifaceted assessment and overcoming various obstacles (Kumar et al., 2017, pp. 596-597; Dogan et al., 2020, pp. 1-2).

Turkey's energy policy has undergone a major shift, placing greater emphasis on investment in RES while decreasing the nation's reliance on non-renewable energy. This shift not only contributes to achieving the country's environmental goals, but also has the potential to increase energy security (Ağbulut et al., 2023, p. 1; Cetin et al., 2018, pp. 365-89). That said, the implementation of multi-criteria decision-making (MCDM) approaches is important for ensuring the efficient and sustainable design of energy systems. By evaluating environmental, economic, technical, and institutional aspects together, MCDM enables stakeholders to determine the most effective choice in designing energy systems. In the assessment of energy resources, MCDM methods help to find the most appropriate solution by considering environmental, economic and technical criteria together (Kumar et al., 2017, p. 597). To overcome the multidimensional problems of the energy industry in Turkey, MCDM stands out as an important decision support tool. Turkey's energy policy highlights the importance of boosting renewable energy resources; in light of this, MCDM methods provide critical support to decision-makers by evaluating and ranking different energy alternatives according to factors like cost, environmental impact, reliability, and sustainability (Avşar Özcan et al., 2022, p. 520). These methods are important tools that contribute to both increasing efficiency in the energy industry and achieving environmental goals (Kumar et al., 2017, p. 597).

In this respect, the application of MCDM techniques to address the multifaceted issues within Turkey's energy sector will both improve the performance of RES and support the integration of economic development with environmental goals. The role of MCDM in managing environmental impacts, which are increasing in parallel with increasing energy demand and dependence on fossil fuels, is crucial for Turkey to achieve its sustainable energy goals. Hence, this research employs the MAXC and MUTRISS models in an MCDM based decision making approach to assess Turkey's renewable energy, economic growth, and emission performance (2000–2021), emphasizing the role of MCDM in decision support systems. The MAXC method is preferred in decision-making processes because it provides an objective and simple calculation process (Gligorić et al., 2024)). The MUTRISS method, on the other hand, is preferred in decision-making processes that consider uncertainties and different scenarios because it provides flexible and reliable solutions (Zakeri et al., 2023). Both the MAXC and MUTRISS methods were chosen for their innovative approaches, which offer a fresh viewpoint in the existing literature.

The layout of the research is as follows: The introductory segment defines the research aims and provides essential background information. Next, an exploration of the relevant literature is conducted. The following section focuses on the dataset and the methodologies applied in the study, namely MAXC and MUTRISS. Afterward, the results derived from these methodologies are analyzed, including a comparative assessment to validate their effectiveness. Lastly, the final section offers a comprehensive review of the overall findings.

1. Literature Review

Providing a broad overview, this chapter reviews diverse research areas documented in the literature and elaborates on the methodologies used to evaluate Turkey's performance related to renewable energy, economic growth, and carbon emissions. These research areas include “Renewable Energy and Energy Policy”, “Environmental Performance and Emissions”, “Energy Sector and Decision Making Methods”, “Energy Production and Economic Performance”, “Economic Performance and Decision Making Methods”, “Green Economy and Environmental Performance”, and “Energy Security and Sustainability”.

Goswami et al. (2022) applied the combined MEREC-PIV model to examine renewable energy sources in India, concluding that hydroelectric energy was the most favorable option, while biomass energy was the least preferred alternative. Wang et al. (2021) utilized the G-AHP and WASPAS approaches to identify the best renewable energy sources in Vietnam, concluding that solar energy was the leading option. Krysiak and Kluczek (2021) explored the challenges of integrating multi-criteria sustainability assessment methods into European Union energy policy. Their research employed the AHP method on three types of photovoltaic technologies, ultimately concluding that strip photovoltaic technology is the most sustainable option over its full life cycle. Çapraz (2024) identified solar, geothermal, wind, biomass, and hydropower as the most suitable resources, respectively, by using hybrid AHP-ARAS and SWARA-TOPSIS methods to determine the order of importance for renewable energy resources in Denizli province, supported by various sensitivity analyses.

Li et al. (2024) have determined solar energy to be the most suitable option for sustainable energy in Malaysia by applying the AHP approach to calculate weights based on a total of 19 criteria. They evaluated the alternatives using a fuzzy MCDM approach, and the results were validated using the fuzzy TOPSIS and SAW methods. Ali (2023) used the TOPSIS method in a neutrosophic environment to identify energy policies and renewable energy systems in Egypt, helping to identify renewable energy sources suitable for different policies by analysing seven criteria and seven alternatives. Gezen Ucar (2024) prioritized Turkey's energy resources using energy security, environmental, technical, economic, and technical criteria, concluding that economic and technological factors are prioritized, nuclear energy policy of the MENR is unsupported, and natural gas, lignite, and hydropower policies are supported, while wind energy targets are deemed unachievable. Delcea et al. (2024) employed the ARDL framework for analyze factors affecting CO2 emissions in Romania (1990–2023) and performed policy rankings with Fuzzy ELECTRE, TOPSIS, DEMATEL, and VIKOR methods. They found that renewable energy reduces emissions, while patent applications and urbanization have positive effects. Economic growth alone does not increase emissions, and effective environmental policies can mitigate this. Florindo et al. (2018) calculated Brazilian beef exports’ carbon footprint and identified improvement actions using TOPSIS methods and fuzzy set theory, showing that the animal production stage has the greatest impact and that carbon footprint can be reduced by increasing productivity.

Atıcı and Ulucan (2009) examined the utilization of the ELECTRE and PROMETHEE methods within the Turkish energy sector, focusing on the evaluation of hydropower and wind power projects. They highlighted that the implementation of analytical approaches can improve the rationality of the decisions made. Sağır and Doğanalp (2016) developed a model utilizing the TOPSIS method to evaluate energy resources in Turkey, ranking various energy alternatives based on factors that include environmental impact, cost, sustainability, and reliability, ultimately identifying renewable energy sources as the most favorable option. Avcı (2019) conducted an evaluation focusing on the financial situation of firms in Turkey’s energy sector, employing the ARAS and MOORA methods. This analysis resulted in differing rankings between the two approaches.

Ilgın and Alkan (2020) identified four key factors limiting the widespread adoption of renewable energy in Turkey and proposed solutions to mitigate their impact by applying quality level analysis and multi-dimensional evaluation approaches (DEMATEL and analytical network process). Avşar Özcan et al. (2022) evaluated investment alternatives for energy production in Turkey using methods such as TOPSIS, PROMETHEE, AHP, COPRAS, VIKOR, ELECTRE, and ANP. They found that renewable energy sources, particularly wind and hydropower, significant role in an eco-friendly energy approach, while natural gas is expected to remain an important investment source for many years. The high correlation among the methodologies indicated that the criteria were consistent regarding sustainability.

Karaaslan and Aydın (2020) employed the COPRAS, AHP, and MULTIMOORA methods to assess and identify the optimal renewable energy options for Turkey, thereby establishing that solar, biomass, geothermal, wind, and hydro were the most viable alternatives. Danışan et al. (2018) used AHP, ANP, TOPSIS, ELECTRE, VIKOR and PROMETHEE approaches to assess the investment priorities of sustainable energy alternatives in Turkey and concluded that investments should be made in wind and hydroelectric power plants. Koç et al. (2023) evaluated five projects to reduce the natural gas consumption of Ulusoy Tekstil using the MAUT method and concluded that the project with the highest benefit should be weighted with the benefit values obtained from each project.

Menten and Çekiç (2023) ranked the G20 countries in terms of their energy output by employing the TOPSIS technique. Their findings revealed that China and Saudi Arabia ranked the lowest in the environmental perspective, with the criteria weighted according to environmental considerations. Hasheminasab et al. (2023) introduced a new framework to assess energy poverty (EP) in EU countries, evaluating 27 nations based on energy consumption, accessibility, and sustainability using ITARA, with Denmark, Sweden, and Estonia performing the best via the MARCOS methodology. Brodny and Tutak (2023) examined the sustainability performance of the EU-27 countries using five different multi-criteria analysis methods (CODAS, EDAS, TOPSIS, VIKOR and WASPAS) to assess the progress in sustainable energy and climate change within the European Union. They categorised these countries into four sustainability levels for the years 2010, 2015 and 2020, showing that Sweden and Denmark are the most sustainable. Ren and Lützen (2015) developed a model to identify the most sustainable technology by combining fuzzy AHP and VIKOR methods. They assessed sustainability using technological, economic, environmental and socio-political criteria to reduce transport emissions and analysed technologies such as low-sulphur fuel, scrubbers and LNG. Man et al. (2020) assessed the sustainability assessment of paper manufacturing across its life cycle using TOPSIS, BW and ISWM models with criteria such as energy consumption, water consumption, internal costs and greenhouse gas emissions. They concluded that the most sustainable alternative was to use recovered paper, followed by mixed fibre.

Urfalıoğlu and Genç (2013) used the ELECTRE, PROMETHEE, and TOPSIS methods to analyse Turkey's economic performance within the European Union process. They compared Turkey's economic indicators with those of EU member and candidate countries, and provided strategic insights to improve Turkey's economic development. In his study, Arslan (2023) evaluated Turkey's economic situation throughout the past 38 years by using EDAS and MOORA methods based on macroeconomic indicators and determined criterion weights using Entropy method and determined that 2011 was the best and 1994 was the worst economic performance. Kaya Samut (2024) evaluated Turkey's 100-year economic process (1923-2022) using the TOPSIS method, with criteria such as exports, imports, employment, inflation, and growth rate from 1977 to 2022, and found that 2021 achieved the best results, whereas in 1994, exhibited the weakest performance. Orhan (2020) analysed the macroeconomic performance of EU member states, candidate nations, and potential candidates in 2018 using the ARAS method and found that Turkey outperformed countries such as Greece, Kosovo, Serbia, North Macedonia, Albania, Bulgaria, Montenegro, Croatia and Portugal.

Pınar et al. (2023) assessed Turkey's economic performance from 2020 to 2022 using the TOPSIS and MABAC methods. They concluded that 2021 and 2022 showed the strongest performance, while 2020 had the weakest. The study also revealed that while both methods provided consistent outcomes during economic downturns, they generally led to different rankings overall. Eleren and Karagül (2008) evaluated Turkey's economic performance between 1986 and 2006 using the TOPSIS method and identified 1986 as the most successful year and 1999, 2001, 2006 and 2000 as the years with the worst performance. Altay Topçu and Oralhan (2017) assessed Turkey's economic position within OECD countries by examining macroeconomic indicators like GDP, growth rate, inflation, exports, imports, and employment rate using the ELECTRE and TOPSIS methods. They identified Turkey's economic advantages and shortcomings through a comparative analysis with other OECD nations. Akandere and Zerenler (2022) evaluated the environmental and economic performance of Eastern European countries using the Environmental Performance Index and the CRITICAL-TOPSIS method. Romania performed best and Bosnia and Herzegovina worst. The CRITIC method emphasised ecosystem services as the primary criterion, while ecosystem vitality was the least critical.

Ela et al. (2018) used the TOPSIS method to evaluate the macroeconomic performance of EU member states and Turkey in 2015. They found that Ireland, Cyprus and Poland performed the strongest, while Turkey, Austria and Belgium performed the weakest. The study also revealed a deterioration in economic convergence during the crisis period. Belke (2020) assessed the macroeconomic performance of the G7 countries from 2010 to 2018 using the CRITIC and MAIRCA methods. The United States performed best, while Italy performed worst. Yılmaz et al (2021) analysed the economic and social standing of women in OECD countries using the Entropy-based approach and ARAS technique, finding the countries with the highest status were Norway, Iceland and Sweden, and the countries with the lowest status were Japan and Hungary.

Baydaş et al. (2024) emphasized that the structure of economic and financial data influences MCDM methods using maximum normalization, CODAS, and fuzzy data. They noted that this impact affects the accuracy and framework of green economic and environmental performance evaluations, significantly influencing the decision-making process. In a study conducted by Gökgöz and Yalçın (2023), the analysis conducted with IDOCRIW-weighted SAW, MARCOS and CODAS methods shows that Denmark has the highest energy security among the European Union (EU) countries. This study emphasizes that energy security is an important factor that increases economic growth. Pamucar et al. (2023) found that environmental factors are more important than economic and social factors using WENSLO and ALWAS methods. It was also stated that Canada has the highest level of green growth, followed by the United Kingdom and Germany.

Below are several literature studies that explore the application of the MAXC and MUTRISS methods:

Gligorić et al. (2024) employed the MAXC and TODIFFA methods to evaluate deep learning software tools in large-scale enterprises. Zakeri et al. (2023) focused on material selection, utilizing the MUTRISS method. In a similar vein, Dua and Trung (2024) combined MUTRISS, PSI, and MEPSI methods in his study on material selection for the production of car shock absorbers.

The literature review reveals a substantial body of research investigating sustainable energy performance, GDP growth, and CO_2 emissions in Turkey. Most of these studies apply multi-criteria evaluation techniques such as AHP, TOPSIS, and ELECTRE to examine the environmental, economic, and social impacts of renewable energy sources across different geographical regions. However, the majority of existing research tends to focus on specific regions or single dimensions and thus falls short of providing comprehensive analyses that simultaneously evaluate Turkey's renewable energy policies, economic performance, and CO_2 emissions within a long-term framework. A review of the literature shows that, although there are many studies focused on renewable energy usage, economic growth, and carbon emissions in Turkey, studies that holistically and long-term assess these three dimensions together are quite limited. In particular, studies that evaluate Turkey's renewable energy usage, economic growth, and carbon emission performance in an integrated and long-term manner are scarce. To fill this gap, the present study evaluates Turkey's renewable energy development, economic growth, and carbon emissions performance between 2000 and 2021 using a multi-criteria decision-making (MCDM) approach. While previous research typically investigates these factors separately, this study offers a more integrated assessment aligned with environmental sustainability and national energy policy goals.

Furthermore, this study evaluates Turkey's performance in carbon emissions, renewable energy, and economic growth using innovative MCDM methods such as MAXC and MUTRISS. Given the limited application of these methods in energy and environmental analyses within the current literature, this study aims to contribute a fresh perspective by assessing their effectiveness. By thoroughly examining the impact of renewable energy sources on economic development and carbon emissions, the study aims to provide strategic recommendations for emerging economies like Turkey. Within this framework, it seeks to make a meaningful contribution to policy development related to renewable energy, economic growth, and environmental performance, serving as a key reference for strengthening transition strategies.

This study applies innovative methods such as MAXC and MUTRISS within a broader context to examine Turkey's renewable energy policies, economic growth, and environmental sustainability performance. The integration of these methods with critical areas such as energy security and environmental sustainability demonstrates how they can holistically support environmental and economic strategies and provides a comprehensive evaluation of how multi-criteria decision-making processes can be more effectively adapted to Turkey's renewable energy goals.

2. Dataset and Method

2.1. Dataset

This study investigates Turkey's performance in economic growth, carbon emissions, and renewable energy consumption over the period 2000–2021, utilizing a comprehensive dataset encompassing multiple indicators. The data were compiled from World Bank (WDI) data sources that provide annual information on Turkey's energy consumption, economic performance and environmental indicators. The criteria employed in the study encompass variables such as energy intensity, renewable energy utilization, carbon emissions from the energy sector, gross domestic product (GDP), urban population ratio, and electricity access. These criteria were chosen to assess Turkey's potential to achieve sustainability objectives. The weighting of the criteria was carried out using the MAXC method, while the evaluation of Turkey's performance across alternative years was conducted using the MUTRISS method. These methods provide a strong analytical framework for examining how Turkey's energy and economic policies align with sustainable development goals. Turkey's initial decision matrix for alternative years, based on the aforementioned criteria, is presented in detail in the accompanying Tables 1 and 2.

Table 1. Variables Used in the Study

Criterion	Definition	Unit	Source
CO2	Carbon dioxide (CO2) emissions from Power Industry (Energy)	Mt CO_2e	World Bank (WDI)
REN	Renewable energy consumption	(% of total final energy consumption)	World Bank (WDI)
GDP	GDP	(constant 2015 US$)	World Bank (WDI)
AccessE	Access to electricity	(% of population)	World Bank (WDI)
EnergyI	Energy intensity level of primary energy	(MJ/$2017 PPP GDP)	World Bank (WDI)
Manufact	Manufacturing, value added	(% of GDP)	World Bank (WDI)
UrbanPop	Urban population	(% of total population)	World Bank (WDI)

Table 2. Initial Decision Matrix Created with Data for Turkey Between 2000-2021

Turkey	CO2 min	REN max	GDP max	AccesE max	EnergyI min	Manufact max	UrbanPop max
2000	68.4155	17.3	4.14E+11	99.9	3.25	18.70563	64.741
2001	69.8837	18.1	3.90E+11	99.9	3.17	17.71463	65.34
2002	64.5813	17.5	4.15E+11	99.8	3.15	16.93262	65.974
2003	65.5701	16.3	4.39E+11	99.8	3.16	17.11145	66.602
2004	66.6461	16.8	4.82E+11	99.7	2.95	16.94824	67.225
2005	74.6122	15.3	5.25E+11	99.7	2.82	16.90386	67.84
2006	83.6723	14.2	5.62E+11	99.7	2.92	17.05937	68.45
2007	99.3888	12.5	5.90E+11	99.7	2.99	16.80467	69.053
2008	105.9673	12.5	5.95E+11	99.7	2.91	16.2646	69.651
2009	101.5075	13.1	5.66E+11	99.7	3.06	15.15761	70.241
2010	102.1592	14.2	6.14E+11	100	3.03	15.05397	70.825
2011	113.3949	12.7	6.83E+11	100	2.9	16.44867	71.402
2012	115.9306	13	7.16E+11	100	2.9	15.83375	71.974
2013	109.6142	13.8	7.76E+11	100	2.61	16.27986	72.531
2014	127.7553	11.5	8.15E+11	100	2.57	16.7717	73.077
2015	120.1472	13.3	8.64E+11	100	2.62	16.69619	73.611
2016	131.2401	13.2	8.93E+11	100	2.7	16.59546	74.134
2017	141.2306	11.4	9.60E+11	100	2.69	17.59183	74.644
2018	145.636	11.8	9.89E+11	100	2.57	19.08376	75.143
2019	135.3326	14.1	9.97E+11	100	2.59	18.37747	75.63
2020	131.1506	13.7	1.02E+12	100	2.55	19.13919	76.105
2021	143.6614	12	1.13E+12	100	2.48	22.23805	76.569

2.2. Method

2.2.1. MAXC Method

MAXC is an objective method for assessing the weights of criteria, derived from the anticipated distance to the maximum value. This recognises that criteria weights influence ranking and allows data normalisation since target values (max/min) do not impact weight calculations (Gligorić et al., 2024, pp. 3-7).

Phase 1: Assessment Matrix Construction

The assessment matrix D is defined as:

$$D = [x_{ij}]_{mxn} = \begin{bmatrix} \frac{A}{C} & C_1 & C_2 & & C_n \\ A_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & & x_{2n} \\ & \vdots & & \ddots & \vdots \\ A_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Where:

A = [$A_1, A_2, ..., A_m$]: The collection of alternatives.

C = [$C_1, C_2, ..., C_n$]: The collection pertaining to criteria.

x_{ij}: Indicates the performance rating of alternative A_i based on the evaluation of criterion C_j.

Phase 2: Normalize the values within the decision matrix.

For every j within the limits of $[1, n]$,

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (2)$$

Phase 3: Maximum Criterion Value Extraction

Determine the maximum value for each criterion:

$$r_{ij}(max) = max(r_{ij}: 1 \leq j \leq n), \forall i \in [1,2, ..., m] \quad (3)$$

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Phase 4: Distance Measurement

Determine the difference between the maximum value of each criterion and its respective value:

$$d_{ij} = r_{ij}(max) - r_{ij}, \ \ i = 1,2,\dots,m, \ \ \forall j \in [1,n] \quad (4)$$

Phase 5: Computation Regarding Expected Distances

Assess the expected distance for all criteria.

$$E_j = \frac{\sum_{i=1}^{m} d_{ij}}{m}, \ \forall j \in [1,n] \quad (5)$$

Phase 6: Criterion Weight Calculation

Finally, determine the weight of each criterion:

$$\delta_j = \frac{E_j}{\sum_{j=1}^{n} E_j}, \qquad (j = 1,2,\dots,n) \quad (6)$$

Where δ_j outlines the final weights attributed to the criteria.

2.2.2. MUTRISS Method

The MUTRISS technique was developed to overcome the problems of inconsistent rankings and insufficient involvement of deciders in the MCDM process. Alternatives are assessed within a multidimensional space, while the best alternative is identified by calculating the area of each alternative. This area is calculated using irregular polygons and the alternative with the largest area is selected. The three-stage MUTRISS algorithm is structured as follows (Zakeri et al., 2023, pp. 4-5; Dua and Trung, 2024, pp. 171-172):

Phase 1: The decision matrix $X = (x_{ij})$ is normalized to keep values between 0 and 1. The normalization is conducted as follows:

$$\overline{\overline{x_{ij}}} = \begin{cases} \dfrac{x_{ij}}{\underbrace{max x_{ij}}_{1 \le j \le n}}, for\ benefit - oriented\ criteria \\ \dfrac{\underbrace{min x_{ij}}_{1 \le j \le n}}{x_{ij}}, \ for\ cost - oriented\ criteria \end{cases} \qquad i = 1,2,\dots,m \quad (7)$$

where:

$\overline{\overline{x_{ij}}}$ is the value converted to a normalized scale.

x_{ij} is the original score for alternative i matched with criterion j

The highest and lowest measurements are taken over all alternatives for the respective criteria.

Phase 2: Weighted Normalized Decision Matrix

$$r_{ij} = w_j . \overline{\overline{x_{ij}}} \quad (8)$$

where:

r_{ij} represents the adjusted normalized value based on weights

w_j is the weight associated with criterion j

Phase 3: Calculation of the Alternative Value AV_i

$$AV_i = \left(\left(\sum_{j=1}^{n} r_{ij} \times r_{(i(j+1))} \right) + (r_1 \times r_n) \right) . \sin \varphi \, . 0{,}5, \qquad j + 1 \le n \quad (9)$$

Where:

$\varphi = \frac{360^{\circ}}{n}$ defines the distance between each alternative in a flat geometric space.

$r_{i(j+1)}$ is the corresponding measurement of the same alternative for the next criterion.

$r_1 . r_n$ is the product of the first and last criterion values of the alternative.

3. Findings

This section presents the dependency in terms of renewable energy consumption, carbon emissions, as well as economic growth in Turkey between 2000 and 2021, with results obtained using the integrated MAXC-MUTRISS.

3.1. Findings Obtained Using The MAXC Method

The normalisation is implemented on the initial evaluation matrix presented in Table 2 as in Equation (2), and the adjusted evaluation matrix is formed as illustrated in Table 3.

Table 3. Normalised Decision Matrix

	CO2 min	REN max	GDP max	AccessE max	EnergyI min	Manufact max	UrbanPop max
2000	0.029521	0.056114	0.026812	0.045459	0.051925	0.049263	0.041480
2001	0.030155	0.058709	0.025270	0.045459	0.050647	0.046653	0.041864
2002	0.027867	0.056763	0.026900	0.045413	0.050328	0.044593	0.042270
2003	0.028293	0.052871	0.028450	0.045413	0.050487	0.045064	0.042673
2004	0.028758	0.054492	0.031237	0.045368	0.047132	0.044634	0.043072
2005	0.032195	0.049627	0.034046	0.045368	0.045055	0.044518	0.043466
2006	0.036105	0.046059	0.036411	0.045368	0.046653	0.044927	0.043857
2007	0.042886	0.040545	0.038248	0.045368	0.047771	0.044256	0.044243
2008	0.045725	0.040545	0.038560	0.045368	0.046493	0.042834	0.044626
2009	0.043800	0.042491	0.036700	0.045368	0.048890	0.039919	0.045004
2010	0.044082	0.046059	0.039792	0.045504	0.048410	0.039646	0.045378
2011	0.048930	0.041194	0.044249	0.045504	0.046333	0.043319	0.045748
2012	0.050024	0.042167	0.046368	0.045504	0.046333	0.041699	0.046115
2013	0.047299	0.044762	0.050303	0.045504	0.041700	0.042874	0.046472
2014	0.055126	0.037301	0.052788	0.045504	0.041061	0.044169	0.046821
2015	0.051844	0.043140	0.056000	0.045504	0.041860	0.043971	0.047164
2016	0.056630	0.042815	0.057860	0.045504	0.043138	0.043705	0.047499
2017	0.060941	0.036977	0.062201	0.045504	0.042978	0.046329	0.047825
2018	0.062842	0.038274	0.064075	0.045504	0.041061	0.050258	0.048145
2019	0.058396	0.045735	0.064600	0.045504	0.041380	0.048398	0.048457
2020	0.056591	0.044437	0.065801	0.045504	0.040741	0.050404	0.048761
2021	0.061990	0.038923	0.073329	0.045504	0.039623	0.058565	0.049059

Equation (3) is used to determine the maximum score of each criterion within the normalised assessment matrix, as illustrated in Table 4. 428

Table 4. The Maximum Scores of the Criteria

Criteria	CO2	REN	GDP	AccessE	EnergyI	Manufact	UrbanPop
max	0.062842	0.058709	0.073329	0.045504	0.051925	0.058565	0.049059

With the help of Table 4, Table 3, and Equation (4), the distances from each criterion to the maximum score are calculated, producing the distance matrix illustrated in Table 5.

Table 5. Matrix of the Distances

	CO2 min	REN max	GDP max	AccessE max	EnergyI min	Manufact max	UrbanPop max
2000	0.033321	0.002595	0.046516	0.000046	0.000000	0.009303	0.007578
2001	0.032687	0.000000	0.048058	0.000046	0.001278	0.011913	0.007195
2002	0.034975	0.001946	0.046429	0.000091	0.001598	0.013972	0.006788
2003	0.034548	0.005838	0.044879	0.000091	0.001438	0.013501	0.006386
2004	0.034084	0.004217	0.042092	0.000137	0.004793	0.013931	0.005987
2005	0.030647	0.009082	0.039283	0.000137	0.006870	0.014048	0.005593
2006	0.026737	0.012650	0.036917	0.000137	0.005272	0.013638	0.005202
2007	0.019956	0.018164	0.035081	0.000137	0.004154	0.014309	0.004816
2008	0.017117	0.018164	0.034769	0.000137	0.005432	0.015732	0.004432
2009	0.019041	0.016218	0.036629	0.000137	0.003036	0.018647	0.004054
2010	0.018760	0.012650	0.033536	0.000000	0.003515	0.018920	0.003680
2011	0.013912	0.017515	0.029079	0.000000	0.005592	0.015247	0.003311
2012	0.012818	0.016542	0.026960	0.000000	0.005592	0.016866	0.002944
2013	0.015543	0.013947	0.023026	0.000000	0.010225	0.015691	0.002587
2014	0.007716	0.021408	0.020541	0.000000	0.010864	0.014396	0.002237
2015	0.010998	0.015569	0.017329	0.000000	0.010066	0.014595	0.001895
2016	0.006212	0.015894	0.015468	0.000000	0.008787	0.014860	0.001560
2017	0.001901	0.021732	0.011127	0.000000	0.008947	0.012236	0.001233
2018	0.000000	0.020435	0.009253	0.000000	0.010864	0.008307	0.000914
2019	0.004446	0.012974	0.008729	0.000000	0.010545	0.010167	0.000602
2020	0.006250	0.014272	0.007527	0.000000	0.011184	0.008161	0.000297
2021	0.000852	0.019786	0.000000	0.000000	0.012302	0.000000	0.000000

In line with the data in Table 5, the anticipated distance values (E_j) and the weight values of the criteria (δ_j) for each criterion are assessed using Equation (5) and Equation (6), and are represented in Table 6.

Table 6. Anticipated Distance Values and Criteria Weights

Criteria	CO2	REN	GDP	AccessE	EnergyI	Manufact	UrbanPop
E_j	0.017387	0.013255	0.027874	0.000050	0.006471	0.013111	0.003604
δ_j	0.212686	0.162132	0.340961	0.000607	0.079151	0.160376	0.044087

Based on the δ_j values (criteria weights) in the table, the importance of the criteria applied in the analysis concerning Turkey's sustainable development objectives has been established. With a weight of 0.340961, the GDP criterion underscores the significance of economic growth as a key element of development. This indicates that economic performance has more impact than any other criterion. CO2 emissions have a weight of 0.212686, indicating that environmental sustainability is important but not as dominant as economic growth. Renewable energy use (REN) ranks third with a weight of 0.162132, indicating that energy policy should be considered from a sustainability perspective. Other criteria have lower weights; Manufact (value added production) is important for economic development with 0.160376, while EnergyI (energy intensity) has a lower importance with 0.079151, UrbanPop (urban population ratio) 0.044087 and AccessE (access to electricity) 0.000607. In particular, the low weight of AccessE indicates that access to electricity, while important, is less determinant than other criteria. In general, economic growth and environmental factors stand out as the most important determinants in this analysis, while other factors seem to be less influential.

3.2. Findings Obtained By Using The MUTRISS Method

All criteria from the initial decision framework outlined in Table 2 were adjusted according to Equation (7), taking the criteria's orientation into account, and the adjusted framework is available in Table 7.

Table 7. Decision Matrix Normalisation

	CO2	REN	GDP	AccessE	EnergyI	Manufact	UrbanPop
	min	max	max	max	min	max	max
2000	0.943957	0.955801	0.365643	0.999000	0.763077	0.841154	0.845525
2001	0.924125	1.000000	0.344618	0.999000	0.782334	0.796591	0.853348
2002	1.000000	0.966851	0.366838	0.998000	0.787302	0.761425	0.861628
2003	0.984920	0.900552	0.387980	0.998000	0.784810	0.769467	0.869830
2004	0.969018	0.928177	0.425986	0.997000	0.840678	0.762128	0.877966
2005	0.865560	0.845304	0.464292	0.997000	0.879433	0.760132	0.885998
2006	0.771836	0.784530	0.496551	0.997000	0.849315	0.767125	0.893965
2007	0.649784	0.690608	0.521595	0.997000	0.829431	0.755672	0.901840
2008	0.609446	0.690608	0.525846	0.997000	0.852234	0.731386	0.909650
2009	0.636222	0.723757	0.500484	0.997000	0.810458	0.681607	0.917356
2010	0.632163	0.784530	0.542660	1.000000	0.818482	0.676946	0.924983
2011	0.569526	0.701657	0.603438	1.000000	0.855172	0.739663	0.932518
2012	0.557069	0.718232	0.632334	1.000000	0.855172	0.712012	0.939989
2013	0.589169	0.762431	0.685993	1.000000	0.950192	0.732072	0.947263
2014	0.505508	0.635359	0.719879	1.000000	0.964981	0.754189	0.954394
2015	0.537518	0.734807	0.763680	1.000000	0.946565	0.750794	0.961368
2016	0.492085	0.729282	0.789057	1.000000	0.918519	0.746264	0.968199
2017	0.457276	0.629834	0.848253	1.000000	0.921933	0.791069	0.974859
2018	0.443443	0.651934	0.873812	1.000000	0.964981	0.858158	0.981376
2019	0.477204	0.779006	0.880964	1.000000	0.957529	0.826397	0.987737
2020	0.492421	0.756906	0.897349	1.000000	0.972549	0.860651	0.993940
2021	0.449538	0.662983	1.000000	1.000000	1.000000	1.000000	1.000000

By applying Equation (8) to the weight values of the criteria in Table 6 and each element of the normalized decision matrix in Table 7, the weighted normalized decision matrix is generated, as illustrated in Table 8.

Table 8. Weighted Normalised Decision Matrix

	CO2 min	REN max	GDP max	AccessE max	EnergyI min	Manufact max	UrbanPop max
2000	0.200767	0.154966	0.124670	0.000607	0.060398	0.134901	0.037277
2001	0.196549	0.162132	0.117501	0.000607	0.061922	0.127754	0.037622
2002	0.212686	0.156757	0.125078	0.000606	0.062316	0.122114	0.037987
2003	0.209479	0.146008	0.132286	0.000606	0.062118	0.123404	0.038348
2004	0.206097	0.150487	0.145245	0.000605	0.066540	0.122227	0.038707
2005	0.184093	0.137051	0.158306	0.000605	0.069608	0.121907	0.039061
2006	0.164159	0.127197	0.169305	0.000605	0.067224	0.123028	0.039412
2007	0.138200	0.111970	0.177843	0.000605	0.065650	0.121192	0.039760
2008	0.129621	0.111970	0.179293	0.000605	0.067455	0.117297	0.040104
2009	0.135316	0.117344	0.170645	0.000605	0.064148	0.109313	0.040444
2010	0.134452	0.127197	0.185026	0.000607	0.064783	0.108566	0.040780
2011	0.121130	0.113761	0.205749	0.000607	0.067688	0.118624	0.041112
2012	0.118481	0.116448	0.215601	0.000607	0.067688	0.114189	0.041441
2013	0.125308	0.123614	0.233897	0.000607	0.075208	0.117407	0.041762
2014	0.107515	0.103012	0.245451	0.000607	0.076379	0.120954	0.042077
2015	0.114323	0.119136	0.260385	0.000607	0.074921	0.120409	0.042384
2016	0.104660	0.118240	0.269038	0.000607	0.072701	0.119683	0.042685
2017	0.097256	0.102116	0.289221	0.000607	0.072972	0.126868	0.042979
2018	0.094314	0.105699	0.297936	0.000607	0.076379	0.137628	0.043266
2019	0.101495	0.126302	0.300374	0.000607	0.075789	0.132534	0.043546
2020	0.104731	0.122719	0.305961	0.000607	0.076978	0.138028	0.043820
2021	0.095611	0.107491	0.340961	0.000607	0.079151	0.160376	0.044087

Equation (9) was applied to the weighted normalised decision matrix and AV_i values were calculated for each alternative. Information on these values and the performance ranking of the alternative years is given in Table 9.

Tablo 9. Ranking of Alternatives

Alternatives(Year)	AV_i	Rank
2000	0.032684	5
2001	0.032654	7
2002	0.033686	2
2003	0.032337	8
2004	0.033895	1
2005	0.030985	9
2006	0.028527	14
2007	0.024697	20
2008	0.024123	22
2009	0.024305	21
2010	0.026500	16
2011	0.025355	18
2012	0.025910	17
2013	0.029174	11
2014	0.025432	19
2015	0.029292	10
2016	0.028767	12
2017	0.026887	15
2018	0.028567	13
2019	0.032692	4
2020	0.033001	3
2021	0.032665	6

The results in Table 9 present a ranking that assesses Turkey's annual performance between 2000 and 2021 against the defined criteria. In this ranking, 2004 is ranked first as the year with the highest performance, while 2007 and 2008 are ranked 20th and 22nd as the years with the lowest performance. 2002 is ranked 2nd and 2021 6th. The best performing years generally stand out as years with favourable developments in economic growth (GDP), renewable energy consumption and environmental factors. Other outstanding years include 2019 and 2020, which are ranked 4th and 3rd respectively. Serving as a significant indicator for Turkey's advancement in sustainable development goals, this ranking highlights that more favorable results have been accomplished, especially in periods when efforts to align economic growth, renewable energy, and environmental sustainability have escalated. The low ranking in 2007 and 2008 reflects the years of economic difficulties and environmental problems. As a result, Turkey's development performance varies over the years and it can be said that the years in which a balance between economic growth and environmental sustainability can be achieved show higher performance.

3.3. Comparative Assessment

A benchmark assessment was used to evaluate the effectiveness of the proposed model. Firstly, the MAXC method was compared with the Entropy, CILOS, IDOCRIW and MPSI methods to assess its effectiveness in determining objective weights. The criteria weights derived from each method of objective weighting are shown in Table 10 and Figure 1.

Table 10. Criteria Scores Calculated by Each Objective Weighting Method

Method/Weight Values of Criteria	Weight1	Weight2	Weight3	Weight4	Weight5	Weight6	Weight7
MAXC	0.212686	0.162132	0.340961	0.000607	0.079151	0.160376	0.044087
MPSI	0.371550	0.120305	0.387100	0.000017	0.051540	0.047118	0.022370
ENTROPİ	0.338405	0.094504	0.485807	0.000008	0.032251	0.036400	0.012624
CILOS	0.001874	0.002541	0.001178	0.982226	0.003932	0.002659	0.005590
IDOCRIW	0.362605	0.137281	0.327214	0.004716	0.072497	0.055345	0.040343

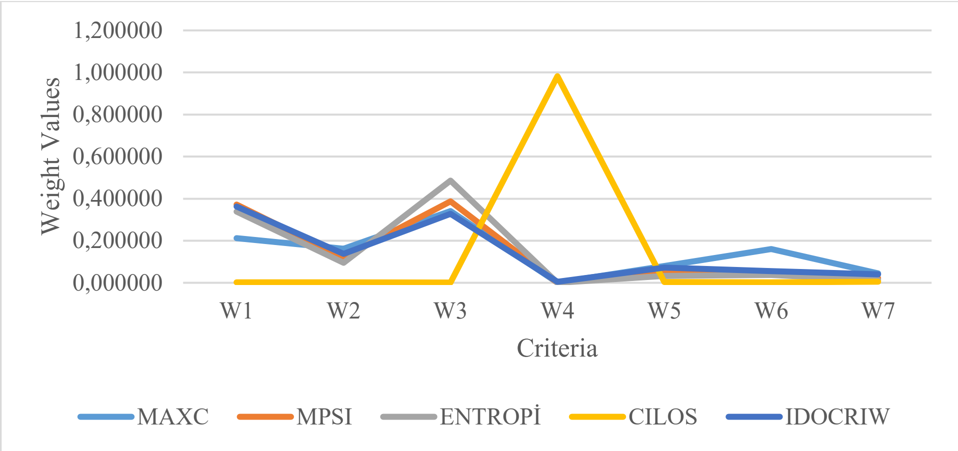

Figure 1. Method-based Criteria Weight Assessment

To assess how valid the objective weighting approaches are in setting criterion weights, Spearman's rank correlation coefficient was employed. The results are outlined in Table 11.

Table 11. Criteria Weight Determination Methods' Correlation Coefficients

	MAXC	MPSI	ENTROPİ	CILOS	IDOCRIW
MAXC	1.000000				
MPSI	0.964286	1.000000			
ENTROPİ	1.000000	0.964286	1.000000		
CILOS	-1.000000	-0.964286	-1.000000	1.000000	
IDOCRIW	0.964286	1.000000	0.964286	-0.964286	1.000000

It is clear from these results that the new MAXC method is highly correlated with all objective weighting methods. The statistical correlation of 1.000000 observed between the MAXC approach and the Entropy method reveals a very strong positive association between these two methods. This shows that the rankings of the methods are fully compatible. The fact that the correlation between the MPSI and IDOCRIW methods and the MAXC method is positive and very close to 1 (0.964286) shows that the rankings of the methods are compatible. On the other hand, the correlation coefficient between MAXC and CILOS is -1.000000, indicating that the relationship between the two methods is negative. Table 13 also indicates that the CILOS technique exhibits a negative relationship with the other approaches. In short, the analyses show that the MAXC method has a strong positive relationship with MPSI and IDOCRIW, a high degree of agreement with ENTROPI and an inverse relationship with CILOS.

The next stage of the comparative analysis is to compare the MUTRISS method with the PIV, SAW and CoCoSo methods. It is important to note that the weights derived from the MAXC method are applied to calculate the final ranking of the options. Ranking of the options by methods can be found in Table 12 and Figure 2.

Table 12. Final Ranking of the Options

	PIV	Rank	SAW	Rank	CoCoSo	Rank	MUTRISS	Rank
A1	0.087573	12	0.713585	11	1.350528	18	0.032684	5
A2	0.089986	16	0.704087	14	1.550266	10	0.032654	7
A3	0.088098	14	0.717544	10	1.595402	8	0.033686	2
A4	0.088700	15	0.712250	12	1.576946	9	0.032337	8
A5	0.082676	9	0.729908	7	1.541118	11	0.033895	1
A6	0.084613	10	0.710630	13	1.503849	13	0.030985	9
A7	0.087672	13	0.690931	16	1.428576	17	0.028527	14
A8	**0.096410**	**20**	**0.655220**	**20**	**1.254999**	**20**	**0.024697**	**20**
A9	0.099189	21	0.646344	21	1.218039	21	0.024123	22
A10	0.101695	22	0.637816	22	1.136990	22	0.024305	21
A11	0.094513	19	0.661412	19	1.322951	19	0.026500	16
A12	**0.092465**	**18**	**0.668671**	**18**	1.456723	16	**0.025355**	**18**
A13	**0.090696**	**17**	**0.674456**	**17**	1.460187	15	**0.025910**	**17**
A14	0.077441	8	0.717804	9	1.696978	5	0.029174	11
A15	0.085550	11	0.695993	15	1.506654	12	0.025432	19
A16	0.073460	5	0.732165	5	1.722885	4	0.029292	10
A17	0.076091	7	0.727614	8	1.656389	6	0.028767	12
A18	0.075939	6	0.732019	6	1.494577	14	0.026887	15
A19	0.070220	4	0.755829	4	1.635064	7	0.028567	13
A20	0.060957	3	0.780648	3	1.908530	3	0.032692	4
A21	0.056556	2	0.792843	2	1.984137	2	0.033001	3
A22	0.047853	1	0.828283	1	2.053088	1	0.032665	6

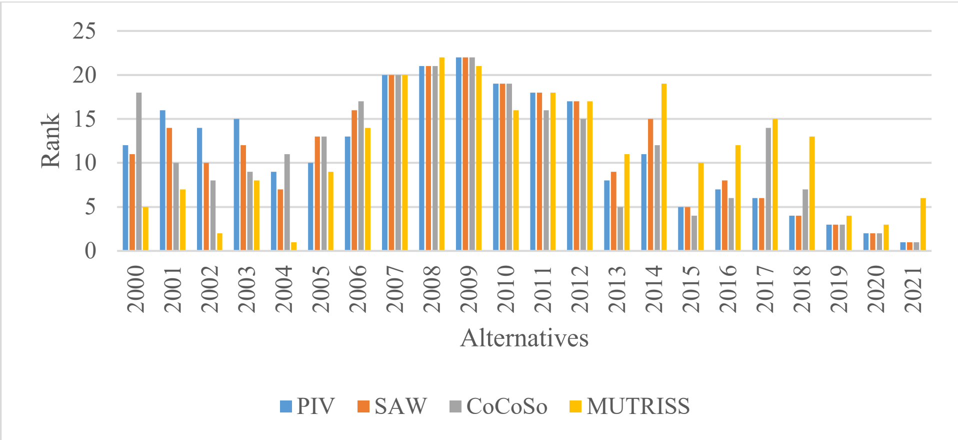

Figure 2. Chart Showing the Final Ranked Alternatives.

Looking at the rankings of the PIV, SAW, CoCoSo and MUTRISS methods in Table 12 and Figure 2, there is some consistency between the methods in certain cases. In particular, while 2007 is ranked 20th for all methods, 2011 and 2012 are ranked 18th and 17th for PIV, SAW and MUTRISS methods respectively. However, the small differences observed between the rankings are due to the fact that each method was evaluated using different criteria and weights. This situation has been observed in many studies in the literature (Ersoy, 2023; Nguyen et al., 2022; Mousavi-Nasab and Sotoudeh-Anvari, 2017; Santiago et al. 2019; Pamučar and Ćirović, 2015). In order to explore the association among the results obtained from various methods, an analysis using Spearman's rank correlation was carried out, and the outcomes are shown in Table 13.

Table 13. Method Comparison: Correlation Coefficients

	PIV	SAW	CoCoSo	MUTRISS
PIV	1			
SAW	0.960474	1		
CoCoSo	0.849802	0.883682	1	
MUTRISS	0.597967	0.727837	0.672501	1

The Spearman rank correlation results show the consistency of the rankings between the methods. The high correlation between PIV and SAW (0.960) shows that these two methods rank the alternatives with similar rankings and provide very consistent results. Furthermore, the high correlation between SAW and CoCoSo (0.884) also indicates that the ranking results of these two methods are largely consistent. However, the correlations between MUTRISS and other methods remain at lower levels, with generally moderately positive relationships (between 0.598 and 0.728). This suggests that the MUTRISS method takes a different approach to ranking and that differences in ranking are produced by more detailed analysis. In particular, it is assumed that MUTRISS provides a more independent and comprehensive assessment than other methods, which may lead to certain differences between rankings. Overall, these results show that MUTRISS provides a more complex and detailed ranking approach, but creates inconsistencies with lower correlation values compared to other methods.

Conclusion

This study aims to assess Turkey's renewable energy capacity, GDP growth patterns, and carbon emission trends from 2000 to 2021 by applying MCDM techniques through the MAXC and MUTRISS frameworks, with the objective of identifying optimal policy solutions at the intersection of energy, economy and environmental sustainability.

The analysis using the MAXC method clearly shows the relative importance of the criteria for Turkey's sustainable development goals. The findings reveal that economic growth (GDP: 0.340961) is the dominant factor in Turkey's development strategies. In terms of environmental sustainability, CO_2 emissions (0.212686) ranking second can be considered a positive development. However, the fact that this weight remains at approximately 62% of GDP shows that environmental concerns still take a back seat to economic interests. The fact that renewable energy consumption (0.162132) ranks third indicates that efforts towards an energy transition require further support. Although other indicators, such as value-added production (0.160376) and energy intensity (0.079151), are moderately important, the low weights assigned to social indicators, such as urban population (0.044087) and access to electricity (0.000607), suggest that the methodology does not adequately capture social dimensions. However, it should be noted that this result is influenced by the sensitivity of objective weighting methods, such as MAXC, to indicators with a wide data range. In light of these results, it is recommended that Turkey adopts hybrid approaches combining objective methods with subjective assessments to enable its sustainable development policies to address the economic, environmental and social dimensions more balanced.

In analysing Turkey's yearly performance, the MUTRISS analysis highlighted the connections among environmental factors, economic growth, and renewable energy consumption. While 2004 ranked first as the year in which Turkey had the highest performance, 2007 and 2008 were the years with the lowest performance. These results show how economic crises and environmental issues can affect Turkey's development performance. Furthermore, higher performance was achieved in 2019 and 2020, with the use of renewable energy and environmental sustainability targets coming to the fore. Pointing out the requirement for a coordinated approach, these findings stress the importance of acknowledging both environmental and economic aspects in fulfilling Turkey's sustainable development goals.

In addition, the validity of the MAXC and MUTRISS methods was tested by comparing them with the other MCDM methods (MPSI, ENTROPI, CILOS, IDOCRIW, PIV, SAW, CoCoSo). The MAXC method was found to be highly correlated with the other objective weighting methods. In particular, the correlation coefficient of 1.000000 between the MAXC and Entropy methods indicates that the rankings between these two methods are fully compatible. Furthermore, the positive correlation between MAXC and MPSI and IDOCRIW also shows that the rankings are highly compatible (correlation coefficient of 0.964286). However, the correlation coefficient of -1.000000 between MAXC and CILOS shows a negative relationship between these two methods. The negative correlation of CILOS with the other methods indicates that this method offers a different ranking approach.

On the other hand, the comparative analysis showed some consistency between the PIV, SAW, CoCoSo and MUTRISS methods, but also differences. The Spearman's rank correlation analysis indicates a noteworthy correlation coefficient of 0.960 for PIV in relation to SAW, while the correlations of MUTRISS with the other methods are comparatively lower, falling between 0.598 and 0.728. This suggests that MUTRISS has a more independent ranking approach and produces differences in rankings. Furthermore, considering that the criteria used by different scoring methods and the weight given to these criteria may differ, it can be said that although MUTRISS provides a more comprehensive assessment, it may create some differences in ranking consistency compared to other methods.

The reliability and validity of the MAXC and MUTRISS methods were strongly supported by the analyses. The MAXC method shows a high degree of correlation with other objective weighting methods and provides consistent and reliable results, especially when analysing factors such as economic growth and environmental sustainability. The close correspondence in rankings produced by the Entropy, MPSI, and IDOCRIW methods lends support to the reliability of MAXC, while the inverse correlation with CILOS suggests that this method utilizes an alternative evaluation strategy, leading to variations in the ranking results.

The MUTRISS method also provided a more independent ranking approach and was able to produce differences in the rankings. The fact that MUTRISS shows lower correlations than the other methods shows that this method provides a more comprehensive evaluation and analyses the alternatives in more detail. However, this independent approach may in some cases lead to differences in ranking consistency. In general, both methods provide reliable and valid analyses in the context of achieving sustainable development goals, but as the criteria and weightings used are different, inconsistencies in the rankings may occur from time to time.

This study demonstrates that the MAXC and MUTRISS models are reliable and valid tools for evaluating Turkey's performance in renewable energy, economic growth, and environmental sustainability. Both methods offer complementary analytical perspectives in multi-criteria decision-making processes, thereby enhancing the robustness of complex sustainability assessments. However, due to methodological differences—particularly in weighting schemes and evaluation criteria—some inconsistencies in rankings are to be expected. These inconsistencies highlight the need for more critical and interdisciplinary approaches to address the delicate balance between economic development and environmental protection.

To achieve its sustainable development goals, Turkey must prioritize strategic policies aimed at improving energy efficiency, promoting the effective use of renewable energy sources, and reducing carbon emissions. Additionally, incorporating more comprehensive and long-term datasets into the analysis will enhance the accuracy and depth of sustainability policy evaluations. This, in turn, will support the development of more targeted, context-sensitive strategies that align with Turkey's unique socio-economic and environmental conditions.

To ensure a more inclusive evaluation of sustainable development policies, it is crucial to integrate social indicators such as education level, income inequality, and energy poverty into the analysis dataset. These indicators will enable the formulation of holistic policy recommendations that consider not only environmental and economic dimensions but also social sustainability.

Moreover, employing hybrid models that integrate objective (e.g., MAXC) and subjective (e.g., AHP) weighting methods can improve methodological diversity and yield more balanced results. Future studies should also investigate in detail why certain methods, such as CILOS, produce inverse correlations and assess the reliability of decision-making processes under uncertainty using fuzzy multi-criteria decision-making (MCDM) techniques.

In light of these findings, it is recommended that future research maintain methodological flexibility while producing more applicable and comprehensive outcomes for policymakers. On Turkey's path to sustainable development, taking decisive and integrated steps to balance energy, economic, and environmental priorities is of critical importance. Ultimately, this study underscores the importance of employing a balanced, multidimensional approach to sustainability assessment. By leveraging both objective and subjective MCDM models, future research can better inform policy frameworks that reconcile economic ambition with environmental responsibility.

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